

SEMICONDUCTOR MEMORY DEVICE WITH A DECOUPLING CAPACITOR

This application claims priority from Korean Patent Application No. 2003-04196,
5 filed on January 22, 2003, the contents of which are incorporated by reference in their
entirety.

FIELD OF THE INVENTION

The present invention relates to a semiconductor memory device and, more
10 particularly, to a random access memory device with a decoupling capacitor.

BACK GROUND OF THE INVENTION

A semiconductor memory device includes a memory cell array for storing data
information. Data, e.g. 0 or 1, is written in or read out from each memory cell of the array.
15 Read and write operations can be carried out by a read means and a write means,
respectively, or by one read/write means depending on a semiconductor memory device. In
the case of DRAM devices, for example, read and write operations are carried out through a
well-known sense amplifier. In the case of SRAM devices, a read operation is carried out by
a sense amplifier and a write operation is carried out by a write driver.

20 An example of a sense amplifier in a DRAM device is disclosed in U.S. Patent No.
6,337,823 entitled RANDOM ACCESS MEMORY DEVICE CAPABLE OF MINIMIZING
SENSING NOISE. An example of a sense amplifier in a SRAM device is disclosed in U.S.
Patent No. 6,160,747 entitled SEMICONDUCTOR MEMORY WITH AUTO-TRACKING
BIT LINE PRECHARGE SCHEME.

25 Read and write operations consume larger current amounts. This large current
consumption decreases a power supply voltage and increases a ground voltage creating a
power noise when performing a read or write operation. More particularly, a sensing margin
is reduced because of the power noise, decreasing operating speed. Decreasing the operating
speed may further drain the power supply voltage.

SUMMARY OF THE INVENTION

30 It is an object of the present invention to address the disadvantages associated with
prior art semiconductor devices.

It is another object of the invention to provide a semiconductor memory device capable of reducing power noise.

It is yet another object of the invention to provide a semiconductor memory device capable of improving operating speed.

5 It is yet another object of the invention to provide a decoupling capacitor for a semiconductor memory device.

A semiconductor memory device comprises a core block including a plurality of sub-arrays and a plurality of sense amplifier regions. A plurality of first voltage supply lines is capable of supplying a first operating voltage to the plurality of sense amplifier regions. A
10 plurality of second voltage supply lines is capable of supplying a second operating voltage to the sense amplifier regions. And a charge storing region is arranged at one side of the core block and includes charge storing means connected to the first and second voltage supply lines.

15 BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the present invention and many of the attendant advantages thereof, will become readily apparent as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference symbols indicate the same or similar
20 components.

Fig. 1 is a block diagram of a semiconductor memory device according to a first embodiment of the present invention.

Fig. 2 is a layout diagram of the core block and the decoupling capacitor shown in Fig. 1.

25 Fig. 3 is a cross-sectional view of the a dotted line A-A' shown in Fig. 2.

Fig. 4 is a block diagram of a semiconductor memory device according to a second embodiment of the present invention.

Fig. 5 is a layout diagram of the core block and the decoupling capacitor shown in Fig. 4.

30 Fig. 6 is a block diagram of a semiconductor memory device according to a third embodiment of the present invention.

Fig. 7 is a layout diagram of the core block and the decoupling capacitor shown in Fig. 6.

Fig. 8 is a bit line voltage variation according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the invention will be more fully described with reference to the attached drawings. A semiconductor memory device of the present invention will be described using a DRAM device. A person of reasonable skill should realize the present invention is not limited to the DRAM device but encompasses any type of semiconductor memory technology. Lines for supplying a power supply voltage and a ground voltage can be named by various terms. For example, such lines can be named voltage lines, voltage supply lines, distribution lines, or the like. Here, a line for supplying a power supply voltage are termed voltage supply lines for simplicity.

Fig. 1 is a block diagram of a semiconductor memory device according to a first embodiment of the present invention. Referring to Fig. 1, a semiconductor memory device 100 of the present invention comprises a plurality of, core blocks, e.g. blocks 110, 120, 130, and 140, arranged in a matrix shape. A row selector block is disposed at one side and a column selector block is disposed at the other side of a corresponding core block. For example, a row selector block 110A is disposed at a bottom side of a core block 110 and a column selector block 110B is disposed at a right side of the block 110. A row selector block 120A is disposed at a bottom side of a core block 120 and a column selector block 120B is disposed at a left side thereof. A row selector block 130A is disposed at a top side of a core block 130 and a column selector block 130B is disposed at a right side thereof. A row selector block 140A is disposed at a top side of a core block 140 and a column selector block 140B is disposed at a left side thereof. Although not shown in Fig. 1, a peripheral circuit block may be arranged between the core blocks 110 and 120 and the core blocks 130 and 140.

Charge storing regions are arranged at both sides (that is, bottom and top sides) of each core block, respectively. For example, charge storing regions 150T and 150B are laid out at upper and lower sides of a core block 110, respectively. Charge storing regions 160T and 160B are laid out at top and bottom sides of a core block 120, respectively. Charge storing regions 170T and 170B are laid out at top and bottom sides of a core block 130, respectively. Charge storing regions 180T and 180B are laid out at top and bottom sides of a core block 140, respectively. A decoupling capacitor for preventing a power noise caused at a sensing operation is formed at each charge storing region. Since a charge storing region is formed along the top and bottom side of a core block, it is possible to form a decoupling capacitor of a considerably large size. As a charge storing means, a decoupling capacitor will

be connected to voltage supply lines for supplying operating voltages to sense amplifiers. This will be described below.

Charges consumed at a sensing operation are firstly supplied from a decoupling capacitor and then supplied from a power supply circuit (or externally) through voltage supply lines. In the case that no decoupling capacitor exists, consumed charges are supplied only from voltage supply lines. It is difficult to supply instantaneously consumed current to sense amplifiers without delay. This is because of voltage supply line loading. On the other hand, decoupling capacitor is used as an auxiliary power supply device, instantaneously consumed current is firstly and quickly supplied from the decoupling capacitor. Accordingly, the power noise caused by a decrease in the power supply voltage and an increase in a ground voltage can be effectively prevented or suppressed.

Fig. 2 is a layout structure of a core block and a charge storing region shown in Fig. 1. Since core blocks in Fig. 1 have the same structure, only one core block 110 is illustrated in Fig. 2. Further, since decoupling capacitors formed at charge storing regions are formed similarly, only two charge storing regions 150T and 150B related to one core block 110 are shown in Fig. 2.

Referring to Fig. 2, a core block 110 comprises a plurality of sub-arrays 10 arranged in a matrix of rows and columns. Each sub-array 10 includes a plurality of word lines WL, a plurality of bit line pairs BL and /BL, and a plurality of memory cells MC arranged at intersections of the word lines and the bit lines. Sense amplifier regions 20 are disposed between sub-arrays 10 adjacent in each column direction. A plurality of sense amplifiers SA is provided at each sense amplifier region 20 and is connected to bit line pairs BL and /BL, arranged along the same column of each of adjacent sub-arrays 10. That is, sense amplifiers SA in each sense amplifier region 20 are shared by adjacent sub-arrays 10.

Word line driving regions 30 are disposed at both sides of respective sub-arrays 10 in each row. A plurality of word line drivers WLD are provided at each word line driving region 30. A part of word lines in each sub-array is selected by drivers WLD of a word line driving region laid out at one side, and the other thereof is selected by drivers WLD of a word line driving region laid out at the other side. Conjunction regions 40 are laid out between word line driving regions 30 adjacent in a column direction.

A voltage supply line VINTA and a voltage supply line VSSA are laid out over sense amplifier and conjunction regions 20 and 40 in each row. The voltage supply line VINTA supplies a power supply voltage to the sense amplifiers 20. The voltage supply line VSSA supplies a ground voltage to sense amplifiers 20. Although not shown in Fig. 2, the VINTA

and VSSA lines may be connected to a power pad (not shown) supplied with an external power supply voltage or to an internal power supply circuit (not shown). A voltage supply line VINTA in each row is connected to a signal line SAH via PMOS transistors disposed at conjunction regions 40 and connected in common to a signal line SAP. A voltage supply line VSSA in each row is connected to a signal line SAL via NMOS transistors disposed at conjunction regions 40 and connected in common to a signal line SAN. As shown in Fig. 2, the signal lines SAH and SAL are connected to sense amplifiers SA of each sense amplifier region 20. With this structure, a power supply voltage as a first operating voltage and a ground voltage as a second operating voltage are supplied to sense amplifiers of each sense amplifier region.

A first end of voltage supply line VINTA is connected to a charge storing region 150T laid out at the top side of a core block 110. A second end of the VINTA is connected to a charge storing region 150B laid out at the bottom side of the core block 110. A first end of the voltage supply line VSSA is connected to the charge storing region 150T and a second end thereof is connected to the charge storing region 150B. Decoupling capacitors are formed at the charge storing regions 150T and 150B, respectively.

Each decoupling capacitor includes an active region, first conductive films P1 formed over the active region, and a second conductive film P2 formed over the active region. In one embodiment, the first conductive films P1 are a polysilicon forming a gate of a MOS transistor. The second conductive film P2 is a polysilicon forming a bit line. One end of a voltage supply line VINTA in each row is connected to the first conductive film P1 of the charge storing region 150T via a contact (formed between a metal and a polysilicon layers), and the other end thereof is connected to the first conductive film P1 of the charge storing region 150B via a contact. One end of a voltage supply line VSSA in each row is connected to the second conductive film P2 of the charge storing region 150T via a contact, and the other end thereof is connected to the second conductive film P2 of the charge storing region 150B via a contact. A second conductive film P2 of the charge storing region 150T is electrically connected to the active region via contacts (formed between a polysilicon and the active region). A second conductive film P2 of the charge storing region 150B is electrically connected to the active region via contacts (formed between a polysilicon and the active region). In one embodiment, the first conductive films P1 form one electrode of the decoupling capacitor and the second conductive film P2 forms the other electrode of the decoupling capacitor.

In one embodiment, only one conductive film P1 can be formed at each charge storing region and only one voltage supply line VINTA can be connected to the conductive film P1. A plurality of first conductive films are connected to a voltage supply line VINTA.

Since a considerably large capacity decoupling capacitor is formed at each top and bottom sides of a core block 110, the power noise caused at a sensing operation is effectively reduced. As the power noise is reduced, the operating speed is improved. For example, referring to Fig. 8, the power noise is relatively reduced when a decoupling capacitor is used, as compared with when no decoupling capacitor is used. As the power noise is reduced, for example, a sensing or operating speed becomes faster by 2ns, as illustrated in Fig. 8.

Fig. 3 is a cross-sectional view of the dotted line A-A' shown in Fig. 2. Referring to Fig. 3, as a means for storing charges, a decoupling capacitor comprises a polysilicon P1 forming a gate over an active region or a semiconductor substrate sub and a polysilicon P2 forming a bit line also over the active region or the semiconductor substrate sub. The polysilicon P1 is one electrode of the decoupling capacitor. The polysilicon P2 the other electrode of the decoupling capacitor. The polysilicon P2 is electrically connected to an impurity region of the active region via plugs PG1 and PG2. The polysilicon P1 is electrically connected to a voltage supply line VINTA via a plug PG3, and the polysilicon P2 is electrically connected to a voltage supply line VSSA via a plug PG4. Each plug can be formed of tungsten, polysilicon, tungsten silicide, or the like.

Fig. 4 is a block diagram of a semiconductor memory device according to a second embodiment of the present invention. Referring to Fig. 4, a semiconductor memory device 200 according to the second embodiment of the present invention includes a plurality of core blocks, e.g. core blocks 210, 220, 230 and 240, laid out in a matrix form. A row selector block is disposed at one side of a core block and a column selector block is disposed at another side thereof. For example, a row selector block 210A is disposed at a bottom side of a core block 210 and a column selector block 210B is disposed at a right side thereof. A row selector block 220A is disposed at a bottom side of a core block 220 and a column selector block 220B is disposed at a left side thereof. A row selector block 230A is disposed at a top side of a core block 230 and a column selector block 230B is disposed at a right side thereof. A row selector block 240A is disposed at a top side of a core block 240 and a column selector block 240B is disposed at a left side thereof. Although not shown in Fig. 4, a peripheral circuit block may be arranged between the core blocks 210 and 220 and the core blocks 230 and 240.

As shown in Fig. 4, charge storing regions 250, 260, 270 and 280 are laid out to surround corresponding core blocks 210-240, respectively. A decoupling capacitor for preventing a power noise caused at a sensing operation is formed at respective charge storing regions 250-280. Since a charge storing region is formed along the periphery of a core block, it is possible to form a considerably large sized decoupling capacitor. As a charge storing means, the decoupling capacitor is connected to voltage supply lines for supplying operating voltages such as a power supply voltage and a ground voltage to sense amplifiers.

Fig. 5 is a layout structure of a core block and a charge storing region shown in Fig. 4. Since core blocks in Fig. 4 have the same structure, only one core block 210 is shown in Fig. 5.

Referring to Fig. 5, a core block 210 comprises a plurality of sub-arrays 10' arranged in a matrix of rows and columns. Each sub-array 10' includes a plurality of word lines WL, a plurality of bit line pairs BL and /BL, and a plurality of memory cells MC arranged at intersections of the word lines and the bit lines. Sense amplifier regions 20' are disposed between sub-arrays 10' adjacent in each column direction. A plurality of sense amplifiers SA are provided at each sense amplifier region 20', and each sense amplifier SA is connected to bit line pairs BL and /BL, which are arranged along the same column, of each of adjacent sub-arrays. That is, sense amplifiers SA in each sense amplifier region 20' are shared by adjacent sub-arrays 10'.

Word line driving regions 30' are disposed at both sides of respective sub-arrays 10' in each row. A plurality of word line drivers WLD are provided at each word line driving region 30'. A portion of word lines in each sub-array is selected by word line drivers WLD laid out at one side. The remaining portion is selected by word line drivers WLD of a word line driving region laid out at the other side. Conjunction regions 40' are laid out between word line driving regions 30' adjacent in a column direction.

A voltage supply line VINTA1 and a voltage supply line VSSA1 are laid out over sense amplifier and conjunction regions 20' and 40' in each row. Further, a voltage supply line VINTA2 and a voltage supply line VSSA2 are laid out over word line driving and conjunction regions 30' and 40' in each column. Voltage supply lines VINTA1 arranged along a row direction are intersected with voltage supply lines VINTA2 arranged along a column direction at conjunction regions 40'. Voltage supply lines VSSA1 arranged along a row direction are intersected and interconnected with voltage supply lines VSSA2 arranged along a column direction at conjunction regions 40'. That is, the lines VINTA1, VINTA2, VSSA1 and VSSA2 are laid out to have a mesh structure.

A voltage supply line VINTA1 in each row is connected to a signal line SAH via PMOS transistors disposed at conjunction regions 40' and connected in common to a signal line SAP. A voltage supply line VSSA1 in each row is connected to a signal line SAL via NMOS transistors disposed at conjunction regions 40' and connected in common to a signal line SAN. As shown in Fig. 5, the signal lines SAH and SAL are connected to sense amplifiers SA of each sense amplifier region 20'. As described above, voltage supply lines VSSA1 arranged along a row direction are intersected and interconnected with voltage supply lines VSSA2 arranged along a column direction at conjunction regions 40'.

A decoupling capacitor is formed at a charge storing region 250 formed to surround the core block 210. The decoupling capacitor of the present invention includes an active region, first conductive films P1' formed over the active region, and a second conductive film P2' formed over the active region. In one embodiment, the first conductive films P1' are formed of a polysilicon for a gate of a MOS transistor, and the second conductive film P2' is formed of a polysilicon for a bit line. The first conductive films P1' form one electrode of the decoupling capacitor and the second conductive film P2' forms the other electrode of the decoupling capacitor. Both ends of a voltage supply line VINTA1 in each row are connected to the first conductive films P1' disposed at upper and lower sides of the core block 210 through corresponding contacts (formed between a metal and a polysilicon), respectively. Both ends of a voltage supply line VSSA1 in each row are connected to the second conductive film P2' formed to surround the core block 210 through corresponding contacts (formed between a metal and a polysilicon), respectively. Both ends of a voltage supply line VINTA2 in each column are connected to the first conductive films P1 arranged at right-handed and left-handed sides of the core block via corresponding contacts (formed between a metal and a polysilicon). Both ends of a voltage supply line VSSA1 in each column are connected to the second conductive film P2' formed to surround the core block 210 through corresponding contacts (formed between a metal and a polysilicon), respectively. The second conductive film P2' is electrically connected to the active region via contacts (formed between a polysilicon and an active region).

A semiconductor memory device according to the second embodiment has a similar operation and attendant advantages as described earlier with the reference to a first embodiment. Description thereof is thus omitted.

Fig. 6 shows a block diagram of a semiconductor memory device according to a third embodiment of the present invention.

Referring to Fig. 6, a semiconductor memory device 300 of the present invention comprises a plurality of core blocks, e.g. core blocks 310, 320, 330 and 340, arranged in a matrix shape. A row selector block is disposed at one side of a core block and a column selector block is disposed at another side thereof. For example, a row selector block 310A is disposed at a bottom side of a core block 310 and a column selector block 310B is disposed at a right side thereof. A row selector block 320A is disposed at a bottom side of a core block 320, and a column selector block 320B is disposed at a left side thereof. A row selector block 330A is disposed at a top side of a core block 330 and a column selector block 330B is disposed at a right side thereof. A row selector block 340A is disposed at a top side of a core block 340 and a column selector block 340B is disposed at a left side thereof. Although not shown in Fig. 6, a peripheral circuit block may be arranged between the core blocks 310 and 320 and the core blocks 330 and 340.

Charge storing regions are arranged at two sides, e.g., left and right sides, (that is, left-handed and right-handed sides) of each core block, respectively. For example, charge storing regions 350L and 350R are laid out at left and right sides, respectively, of core block 310. Charge storing regions 360L and 360R are laid out at left and right sides, respectively, of the core block 320. Charge storing regions 370L and 370R are laid out at left and right sides, respectively, of the core block 330. Charge storing regions 380L and 380R are laid out at left and right sides, respectively, of the core block 340. A decoupling capacitor for preventing a power noise caused at a sensing operation is formed at each charge storing region. Since a charge storing region is formed along the side of the core block, it is possible to form a considerably large sized decoupling capacitor. As a charge storing means, a decoupling capacitor will be connected to voltage supply lines for supplying operating voltages to sense amplifiers.

Fig. 7 shows a layout structure of a core block and a charge storing region shown in Fig. 6. Since core blocks in Fig. 6 have similar structures, only one core block 310 is illustrated in Fig. 7. Further, since decoupling capacitors formed at charge storing regions disposed at left and right sides of each core block are formed similarly, only two charge storing regions 350L and 350R related to one core block 310 are shown in Fig. 7.

Referring to Fig. 7, a core block 310 comprises a plurality of sub-arrays 10'' arranged in a matrix of rows and columns. Each sub-array 10'' includes a plurality of word lines WL, a plurality of bit line pairs BL and /BL, and a plurality of memory cells MC arranged at intersections of the word lines and the bit lines. Sense amplifier regions 20'' are disposed between sub-arrays 10'' adjacent in each column direction. A plurality of sense amplifiers

SA are provided at each sense amplifier region 20'', and each sense amplifier SA is connected to bit line pairs BL and /BL, arranged along the same column, of each of adjacent sub-arrays. That is, sense amplifiers SA in each sense amplifier region 20'' are shared by adjacent sub-arrays 10''.

Continuing to refer to Fig. 7, word line driving regions 30'' are disposed at both sides of respective sub-arrays 10'' in each row. A plurality of word line drivers WLD are provided at each word line driving region 30''. A portion of the word lines in each sub-array is selected by word line drivers WLD driving region laid out at one side. The remaining portion is selected by word line drivers WLD driving region laid out at the other side. Conjunction regions 40'' are laid out between word line driving regions 30'' adjacent in a column direction.

Voltage supply lines VINTA1 and VSSA1 are laid out over sense amplifier and conjunction regions 20'' and 40'' in each row. Voltage supply lines VINTA2 and VSSA2 are laid out over word line driving and conjunction regions 30'' and 40'' in each column. The voltage supply lines VINTA1 are intersected and interconnected with the voltage supply lines VINTA2 at conjunction regions 40'', and the voltage supply lines VSSA1 are intersected and interconnected with the voltage supply lines VSSA2 at conjunction regions 40''. The voltage supply lines VINTA1, VINTA2, VSSA1 and VSSA2 are laid out to have a mesh structure.

A voltage supply line VINTA1 in each row is connected to a signal line SAH via PMOS transistors disposed at conjunction regions 40'' and connected in common to a signal line SAP. A ground voltage supply line VSSA1 in each row is connected to a signal line SAL via NMOS transistors disposed at conjunction regions 40'' and are connected in common to a signal line SAN. As shown in Fig. 7, the signal lines SAH and SAL are connected to sense amplifiers SA of each sense amplifier region 20''. As describe above, voltage supply lines VSSA1 disposed in a row direction are intersected and interconnected with voltage supply lines VSSA2 disposed in a column direction at conjunction regions 40''.

A first end of the voltage supply line VINTA2 is connected to a charge storing region 350L on the left side of a core block 310. A second end thereof is connected to a charge storing region 350R on the right side of the core block 310. A first end of voltage supply line VSSA2 is connected to the charge storing region 350L. A second end thereof is connected to the charge storing region 350R. A decoupling capacitor is formed at each of the charge storing regions 350L and 350R.

Each decoupling capacitor includes an active region, first conductive films P1'' formed over the active region, and a second conductive film P2'' formed over the active

region. In one embodiment, the first conductive films P1" are a polysilicon forming a gate of a MOS transistor, and the second conductive film P2" is a polysilicon forming a bit line. One end of a voltage supply line VINTA2 in each column is connected to the first conductive film P1" of the charge storing region 350L via a contact (formed between a metal and a polysilicon), and the other end thereof is connected to the first conductive film P1" of the charge storing region 350R via a contact. One end of a voltage supply line VSSA2 in each column is connected to the second conductive film P2" of the charge storing region 350L via a contact, and the other end thereof is connected to the second conductive film P2" of the charge storing region 350R via a contact. A second conductive film P2" of the charge storing region 350L is electrically connected to the active region via contacts (formed between a polysilicon and the active region). A second conductive film P2" of the charge storing region 350R is electrically connected to the active region via contacts (formed between a polysilicon and the active region).

In one embodiment, only one conductive film P1" can be formed at each charge storing region. A only one voltage supply line VINTA2 can be connected to the conductive film P1". In one embodiment, a plurality of first conductive films P1" are formed to be connected to voltage supply lines, respectively. The first conductive films P1" form one electrode of a decoupling capacitor and the second conductive film P2" forms the other electrode thereof.

A semiconductor memory device according to the third embodiment has a similar operation and attendant advantages as described earlier with reference to a first embodiment. Description thereof is thus omitted.

As set forth above, a charge storing region is provided to surround a core block or at sides (top, bottom, left or right) of a core block. It should be apparent to one of reasonable skill that a charge storing region is formed to surround a peripheral circuit block. Furthermore, a charge storing region can be formed at only one side of a core block or to surround a core block and a peripheral circuit block. Although not shown in figures, decoupling capacitors can be formed at a conjunction and word line driving regions.

The invention has been described using exemplary preferred embodiments. It is to be understood, however, that the scope of the invention is not limited to the disclosed embodiment. The description is intended to cover various modifications and similar arrangements. The scope of the claims, therefore, should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.